

## Computed Tomography Applications for the Oil and Gas Industry

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### Abstract

X-ray computed tomography (CT) has been used extensively in the oil and gas industry for imaging, quantifying properties, and determining the distribution of fluids in porous rocks (1). Samples imaged range in size from tens of centimeters to a few millimeters, with respective voxel sizes varying from hundreds of microns down to a few microns. Whole cores, retrieved during drilling operations, are scanned for geological characterization and for selection of locations where representative plugs will be taken for laboratory petrophysical measurements. Core plugs are scanned to evaluate heterogeneities, such as laminations, fractures, and vugs (large open voids), that influence fluid flow. During laboratory fluid flow tests performed on core plugs (core floods), CT scanning is used to measure the three-dimensional time-varying fluid saturations. Microplugs are scanned to image the pore structure and determine distributions of fluids within the pore space.

Porosity and permeability are important rock properties that determine the economic value of a petroleum reservoir. Porosity is the fraction of the bulk volume of the material occupied by voids. It characterizes the volume available in porous rock to store fluids in. Permeability is a measure of the ease with which a fluid can be made to flow through the porous rock by an applied pressure gradient. Relative permeability characterizes the flow when multiple phases and fluids coexist within the same porous rock. Relative permeability is the ratio of permeability of a particular phase to the intrinsic rock permeability and it is a function of phase saturation.

To determine the porosity of a core sample, CT scans are performed with the sample saturated successively by two fluids that exhibit strongly contrasting x-ray attenuations, such as air and brine. Knowing the attenuations of the two fluids, the difference between these two sets of images provides the porosity distribution. If two fluids occupy pore space in unknown proportions, CT can be used to determine the saturation of each fluid providing that the fluids have adequate attenuation contrasts. Otherwise, their contrast can be increased by contrast agents, such as iodine or bromine based compounds. Single energy scans are performed for two-fluid saturation measurements. If saturations of three phases (oil, brine and gas) need to be determined, scans are performed at two energies. Dual energy scanning is also used to measure the bulk density and the effective atomic number of the core material. To perform these measurements, the sample needs to be within a coreholder that keeps the sample both immobile, within the x-ray scanner, and provides a means to flow fluid through the core.

Core flooding, monitored by CT scanning can include water, gas, surfactant, polymer, foam, microbial, steam and other floods as dictated by the recovery processes that are most suited for specific reservoirs. Processes such as wormhole formation, gravity segregation, channeling and fingering during oil production, formation damage and fluid

invasion during drilling, and methane hydrate dissociation are also studied by CT imaging. Microfocal CT imaging, using high magnification provides pore network data needed for pore scale modeling and for the study of fluid-rock interactions which, together with the pore topology and geometry, control the flow and trapping of hydrocarbons.

Equipment used for imaging porous rocks ranges from industrial CT scanners and modified medical scanners for large samples, to desktop micro-scanners and synchrotron sources for micron resolution of small samples. While traditional CT equipment was stationary, located in laboratories remote from drilling sites, recent development of a portable, cabinet sized, high-speed whole-core scanner, has permitted field measurements of rock properties and geological interpretation prior to any core degradation that can occur due to its preservation, transport, and storage (2). The continued trend towards higher resolution and less expensive system components is greatly enhancing the capability of specialized CT systems used in the oil and gas industry.

1. Wellington S.L., and Vinegar, H.J., X-ray Computerized Tomography, Journal of Petroleum Technology, 39(8), 1987.

2. Freifeld, B. M., Kneafsey, T. J., Tomutsa, L. and Pruess, J., Development of a portable x-ray computed tomographic imaging system for drill-site investigation of recovered core. 2003 International Symposium of the Society of Core Analysts, Pau, France, Sept 21-24, 2003.